(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 495 418 A1**

# (12) EUROPEAN PATENT APPLICATION

(21) Application number: **92100398.4**

(22) Date of filing: **12.01.92**

(51) Int. Cl.5: **C07C 273/04**, B01J 10/00, B01J 19/24

(30) Priority: **15.01.91 CH 103/91**

(43) Date of publication of application: **22.07.92 Bulletin 92/30**

(84) Designated Contracting States: **AT DE ES FR GB IT NL**

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## (54) System and device for increasing the yield and the production potential of urea reactors.

(57) System for increasing the yield and at the same time the production potential of reactors for urea, formed by the synthesis of ammonia with carbon dioxide at high pressure and temperature, the internal space of said reactors (R) being run through cocurrently by a liquid phase and a gas phase and being divided into compartments ($C_1$ - $C_3$) to avoid the excessive mixing of the entire liquid phase and to allow the intermittent redistribution of the gas in bubbles of a suitable size for increasing the exchange of heat and matter between the two phases, characterized by the fact that at each passage from one compartment to the next the liquid phase and the gas phase are made to flow on separate routes and distributed, each one with a continuous, permanent and even flow.

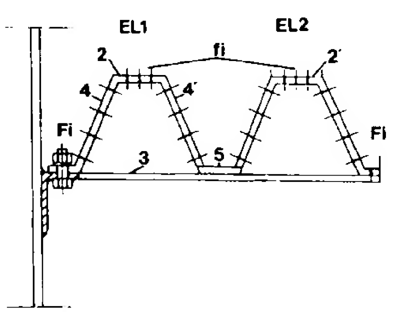



FIG.2

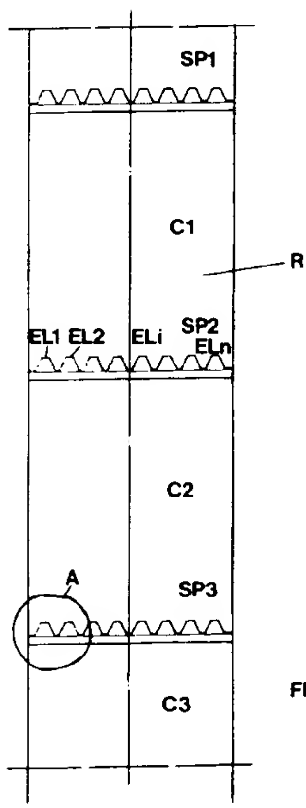



FIG.1

This invention concerns a system for increasing the yield while at the same time increasing the production potential of reactors for urea, formed by the synthesis between ammonia and carbon dioxide at high pressure and temperature, the internal space of said reactors being run through cocurrently by a liquid phase and a gas phase and being divided into compartments to avoid the excessive mixing of the entire liquid phase and to allow the intermittent redistribution of gas in bubbles of a size suitable for increasing heat and matter exchange between the two phases.

The invention also concerns a device for putting into effect the system described, consisting substantially of seven perforated flat baffles or plates distributed transversally in the cylindric reactor shell creating compartments therein, being run through by the flow of gas and of liquid containing urea.

Description of the Known Art.

In modern reactors for the synthesis of urea, the cylindrical shell of the reactor under pressure, inside which two phases, a gas one and a liquid one, flow cocurrently, is divided into compartments by seven perforated plates. The purpose of this configuration is to avoid the excessive mixing of the entire liquid phase contained in the reactor, which would tend to turn it into a complete mixing reactor, thus reducing the urea yield: by dividing the reactor into several stages by means of seven plates the amount of mixing is reduced, and the behaviour of the liquid phase is brought closer to the behaviour of a piston flow reactor, which is notoriously the most favourable for keeping the urea yield relatively high.

By dividing the reactor into seven stages by means of perforated plates, it is also possible to redistribute the gas, flowing upwards along the column, intermittently in smaller bubbles more suitable for increasing heat and matter exchange between the two phases. In effect, the rising showers of bubbles are subjected to coalescence phenomena which progressively increase the size of the bubbles, thus reducing the exchange surface between phases: this negative phenomenon is partly compensated by the redistribution brought about by the perforated flat plates.

However, the cocurrent flow of gas and liquid over each perforated plate produces some adverse effects on both the heat and matter exchange and the urea yield (the latter owing to a diminution of the flow of reagents into the liquid phase, as well as to the reduction in temperature because of the smaller esothermic reaction and also to the reduction in the liquid hold-up in the reactor). In effect, steam and liquid cannot go through the perforations in the flat baffles simultaneously, but are forced to do so alternately by means of forming showers of steam bubbles, separated by liquid pistons in continuous phase. Such an arrangement, as compared with a uniform distribution of the bubbles, with the same amount of steam brings about a higher concentration of bubbles inside the showers alternating with the liquid pistons. The result is a significant increase in coalescence of the bubbles between one plate and the next, increasing their average size, a reduction of the steam/liquid surface, and a worsening of the gas phase/liquid phase exchange; since less steam is exchanged with the liquid phase, the volume available for this phase is also reduced (and the temperature it has reached is also lowered). Moreover, between the plates and the cylinder there is in general a circular slit through which part of the steam may go with less exchange efficiency. Altogether, these causes reduce the urea yield, compared with the yield obtainable with a uniform distribution, instead of the alternating one, of the gas bubbles after each perforated plate.

Another limitative aspect of the State of the Art concerns the possibility of increasing the production potential in reactors in existing plants. Generally the reactor, owing to its potential liquid phase capacity, is very large indeed compared to the nominal urea production required of it, and this fact would lend itself, in principle, to possible increases in production with an almost constant urea yield. However, the bad distribution of gas, the size of the bubbles owing to parasitical coalescence, the matter and heat exchange between phases, the effective volume left to the liquid phase (in which the reaction forming the urea takes place), urea yield, drastically worsen as the gas and liquid capacity increases, so that urea production does not increase proportionately to the increase in total liquid and gas capacity.

SUMMARY OF THE INVENTION

The main purpose of this invention is to provide a method or system to eliminate the abovementioned drawbacks and to increase the synthesis reaction yield and the potential of urea reactors.

Another purpose of the invention is to provide particularly simple and efficient devices to put into effect the system in question. The latter is now characterized by the fact that in every transfer from one compartment into the other the gas and liquid phases are made to flow in mutually separate and distributed ways, each with a continuous, permanent and even flow.

In a preferred embodiment, the working device is characterized by the fact that the perforations in the plates have dimensional and/or shape gradi-

ents, creating area fractions which permit the flow of liquid in the substantial absence of gas bubbles, respectively the sliding and evenly distributed concentration of gas bubbles in the area which would be hard to reach by the liquid.

Therefore, according to an aspect of this invention, the reactor's perforated plates are made in such a way as to allow the more even distribution, with a permanent flow, of the gas bubbles avoiding their coalescing between a plate and the next and the adverse effects of the two-phase movement with showers of bubbles alternating with a continuous liquid flow. The result is an increase in urea yield and of the reactor's production potential.

In a particularly simple and efficient and therefore preferred embodiment, the plates are differently perforated and shaped in such a way as to allow the continuous and permanent flow of both the gas and the liquid, both flowing along routes which are mutually separate and distributed through each plate. The size of the perforations is different for the fractions of area of the plate intended respectively for the flow of liquid and the flow of gas; the size of the perforations in the zones intended for the flow of liquid being such as to impede the passage through them of gas bubbles together with the liquid, but rather to favour their sliding towards zones intended for the gas flow. The fractions of area of the shaped zones intended for the flow of the two phases are distributed in such a way as to ensure the even distribution of the gas bubbles formed through said shaped perforated plates.

The various aspects and advantages of the invention will be made more clear by the description of the embodiment represented in the drawings in which:

- Fig. 1 shows the schematic and partial longitudinal section of a multi-compartment reactor;
- Fig. 2 is an enlarged scale view of the elements forming the plates, comprised in circle A in fig. 1;
- Fig. 3 is an overhand view of the upper part 2 of an element ELi;
- Fig. 3A shows the section along the lien A-A of a rectangular ELi element;
- Fig. 4 is the front view of a plate SPi formed by rectangular elements EL'i-EL'n;
- Fig. 4A (analogous to fig. 2) is an enlarged view of elements EL'm-1, EL'm, EL'm+1 in fig. 4;
- Figs. 5 and 5A are enlarged views of perforated portions on wall 2 (at right angles to the reactor's axis) respectively on walls 4, 4' parallel with the axis.

In fig. 1, R shows the central cylindrical shell of the urea reactor and C1, C2, C3 are the three transversal compartments created by the three plates SP1, SP2 and SP3. These are formed by the lozenge shaped elements EL1 .... ELn which in fig. 2 are trapeze-shaped and which in fig. 4 are rectangular by preference.

Fig. 2 shows that every ELi element is shaped like a Greek key, with a wall shaped like an upside down trapeze formed by the side or lesser base 2 at the top, by the greater base at the bottom 3, by the two slanting sides 4 - 4', and by air-space 5. According to the main aspect of the invention, in the embodiment shown in fig. 2, on the two slanting sides 4 and 4' there are perforations Fi larger than perforations fi on wall 2. By preference perforations fi have a diameter of between 1 and 3 5 mm, better still of about 2 to 3 mm, while the large perforations Fi have a diameter which is almost twice that of fi, 2 to 7, Fi perforations being by preference 3 to 6.

Fig. 3 shows an overhand view of a wall 2 of a rectangular or trapeze-shaped element EL'i.

Fig. 4 shows the front view of a flat baffle, perforated and formed by elements from EL'1 to EL'n which are rectangular, i.e. with walls 4 and 4' parallel with the reactor's axis.

Perforations fi on wall 2 are generally circular as in fig. 5; on the other hand, perforations Fi on walls 4 and 4' may be substantially ellipse-shaped as shown in fig. 5A with O. They are characterized by a greater axis AM and by a smaller axis MI.

## EXAMPLE

Operations have been carried out by simulation on a reactor whose model has supplied, under nominal design conditions, for a production of about 1800 t/d, a yield of 64% on the total flow (liquid plus gas): if the yield were to be (improperly) estimated on the sole liquid phase, it would be about 65.5%. By increasing production up to about 2300 t/d, a diminution in yield was noticed. This confirms, indirectly, a) that the reactor is far too big, b) that an improvement in transport processes inside the reactor would not only increase the yield, compared to nominal conditions, but would also improve said yield which would be maintained throughout notable increases of its potential.

Operations were then continued by simulating with a rigorous mathematical model conditions for a daily production of 2300 t. in the unmodified reactor. A yield (simulated) was obtained of 61.3% which, if based (improperly) on the sole liquid phase would yield (fintitiously) 63.5%. The absence of a number of data under these conditions does not allow of immediate confirmation, but it would seem that the effective yield predicted by the model under increased production conditions is

reasonably close to reality.

Simulation (through the model) of introducing into the reactor new plates also and above all in the section which has not got any at present (i.e., the 16 metres of the lower T.L.) was then carried out. The model coherent with the invention has shown (for the potential of 2300 t/d already achieved) a yield of 65.8% (+4.5% absolute) in respect of the total flow (equal to, improperly, 66.7% on the liquid phase, but with a drastic reduction in steam).

It has also been confirmed that such yield can be maintained for further increases in potential up to 2700 t/d (if that were made possible by the other equipment in the plant). This is a further advantage of the new solution put forward.

Consequently, in theory, under the conditions taken into consideration, an increase in yield (simulated) of 4.5% absolute could be obtained and further increases in production would be tolerable.

Some elements resulting from experiments are given below.

In the description which follows, linear dimensions for baffles and for the passage of liquids are indicative. If necessary for construction purposes, they can be varied by about 5-10%.

This also concerns the number of perforations per m2 both where the liquid phase and the gas phase run through.

On the other hand, the size of the perforations for the gas phase must be considered unchangeable while those for the liquid phase are virtually so.

Finally, it is confirmed that the number of perforations per m2 for the gas phase and the liquid phase should be read as referred to the areas for the gas phase and the liquid phase and not to the total area (gas plus liquid).

Numbering of the plates (suggested, or actually existing, for that part which has not been replaced) begins at the lower tangential line (T.L.) of the reactor (not shown on drawings).

In the same way, when the plates are being installed they should be rotated alternately (in respect of the dome directrix) by 60°-90°, in so far as fastening points allow.

It has been found that, on the whole, the following instructions should be followed when making the plates:

- the thickness of the metal should not be more than 3.5-4 mm, to permit the punching of the perforations;
- the plates should be oriented alternately, for example fixing them at right angles or at 60°;
- perforations for the installation should be made on that portion of the sheet metal reserved for the passage of liquid;
- perforations per square metre for the surface intended for the passage of gas, should be inderstood as referring to the entire surface of the sheet metal, even that which after being folded becomes lateral (vertical);
- perforations for the gas should be made in equilateral triangular links with a 24 mm pitch;
- after the plate has been shaped it is essential that the baffles are closed at the ends with vertical walls welded to the terminal sections creating a seal to avoid gas escaping from the sides;
- to make up for the thinness suitable supports or stiffeners can be applied to the sheet metal after perforating and shaping;
- the gas should be introduced into the lower part through a horizontal tube with multiple perforations set at right angles to the baffles of the lowest plate: if this were not possible, it would become necessary to arrange two plates, with baffles at right angles between them, close to one another (300+500 mm) which would obtain the same result (since the lower plate would act as distributor for the upper plate).

The plates should be at a distance of about 2.4 m.

Perforations for the gas could, in principle, be varied from one plate to the other, with a perforated area decreasing from bottom towards the top: however, with the plates arranged according to the invention, it is possible to maintain even perforations equal to the maximum perforations required for the lower plate. This simplifies construction and installation procedures. In the upper plates, where the vapours (gas) are gradually decreasing this means adjusting the ever increasing level of the liquids inside the domes and a head of gas getting smaller and smaller (part of the perforations intended for the passage of gas will therefore be used by the liquid). In a preferred embodiment;

- perforations for the gas (in the present case) were 2000 holes/(m2 of relative area) with a diameter $\phi$ = 3 mm; arranged as an equilateral triangle (preferred arrangement), this means a distance between perforations for example of 24 mm (and a fraction of perforated area, on the area intended for gas, of 1.4%) (fig. 5);
- perforations for the liquid (in the present case), 600 holes/(m2 of relative area) with diameter $\phi$ = 8 mm, arranged as an equilateral triangle with a distance of 43 mm. Where oval perforations are used (fig. 5A), their axes are 4 mm - 6 mm, interspersed in the same way (with a fraction of perforated area of about 3% of the area for the liquid).

Obviously, the metallic strips bearing the perforations, after being folded and installed should be bolted one to another, leaving an edge for the alternating overlap from one dome to the next.

For the sake of clarity and illustrative simplicity, the invention has been described with reference to the embodiments shown in the drawings. These however are subject to all those variations, substitutions, modifications, etc. which being available to the average technician in this field can be considered as falling naturally within the wider scope and spirit of the invention.

## Claims

1. System for increasing the yield while at the same time increasing the production potential of reactors for urea, formed by the synthesis of ammonia and carbon dioxide at high pressure and temperature, the internal space of said reactor being run through cocurrently by a liquid phase and a gas phase and being divided into compartments to avoid the excessive mixing of the entire liquid phase and to allow the intermittent redistribution of the gas in bubbles of a size suitable for increasing heat and matter exchange between the two phases, characterized by the fact that each time the liquid phase and the gas phase pass from one compartment into the next they are made to flow through mutually separate routes and distributed each with an even, continuous and permanent flow.

2. System according to claim 1, characterized by the fact that the separation of the flows and their being made to flow evenly, continuously and permanently are achieved by giving gradients in size and/or shape to the openings leading from one compartment to the next so as to create fractions of area where the flow of one phase predominates, separate from those where the other phase flows.

3. Device for the installation of the system according to the foregoing claims, substantially consisting of seven perforated flat baffles or plates arranged transversally inside the reactor's cylindrical shell, creating compartments, through which flow the gas and the liquid containing urea, characterized by the fact that the plate perforations have size and/or shape gradients creating fractions of area permitting the flow of liquid with the substantial absence of gas bubbles, respectively and separately the sliding and evenly distributed concentration of bubbles in the area unlikely to be touched by the liquid.

4. Device according to claim 3 in which the plates are formed by rectangular or trapezoidal lozenges, characterized by the fact that the parallel (4, 4') or slightly slanted sides have perforations (Fi) on the reactor's axis larger than those (fi) on the side (i) at right angles with said axis.

5. Device according to claim 4, in which the large perforations (Fi) have a diameter of 2 to 6 preferably of about 4.5 mm, and the small perforations (fi) have a diameter of 1.5 to 3.5 preferably of about 2.5 mm.

6. Device according to claim 3, characterized by the fact that the smaller perforations (fi) are round and the larger ones (Fi) are oval-shaped.

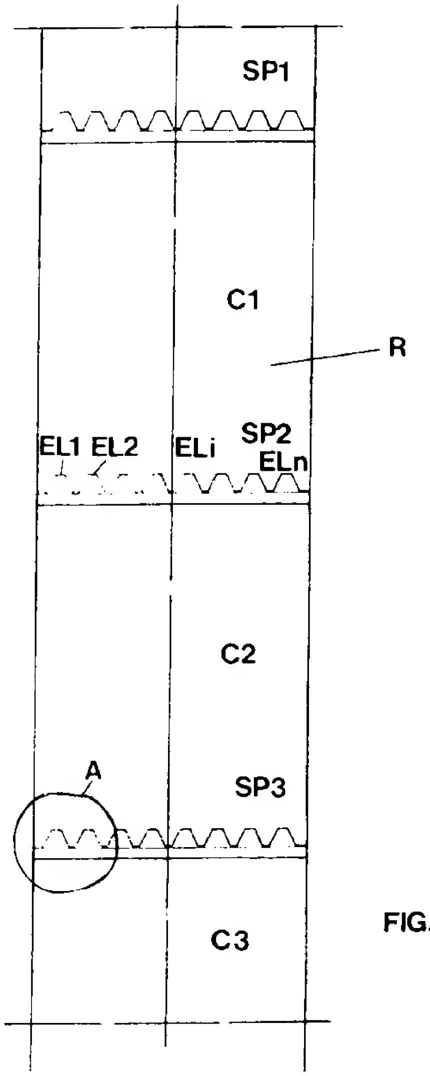
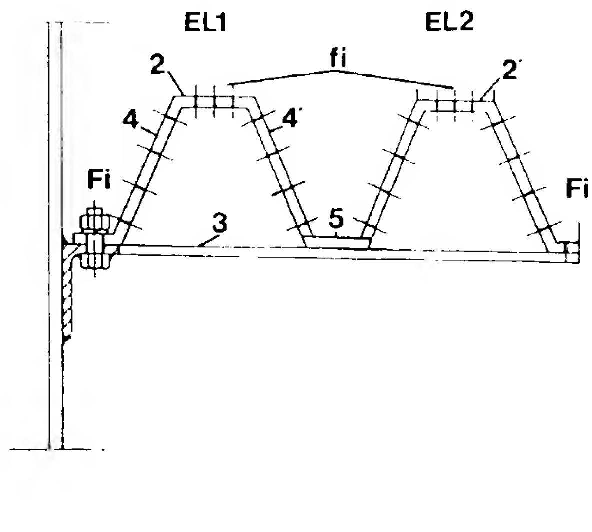



FIG. 1

FIG. 2



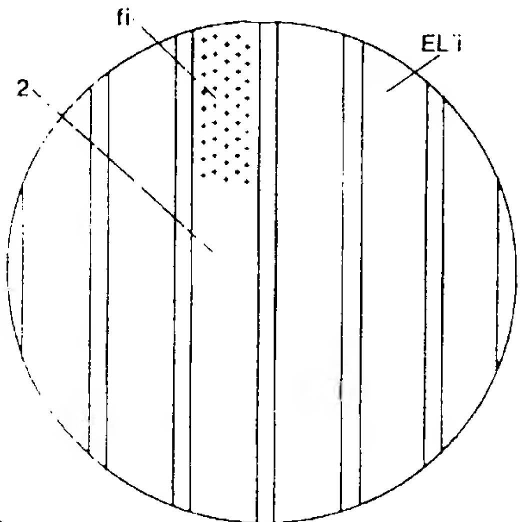



FIG.3

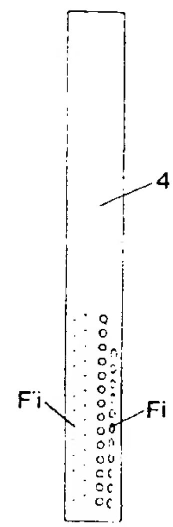



FIG.3A

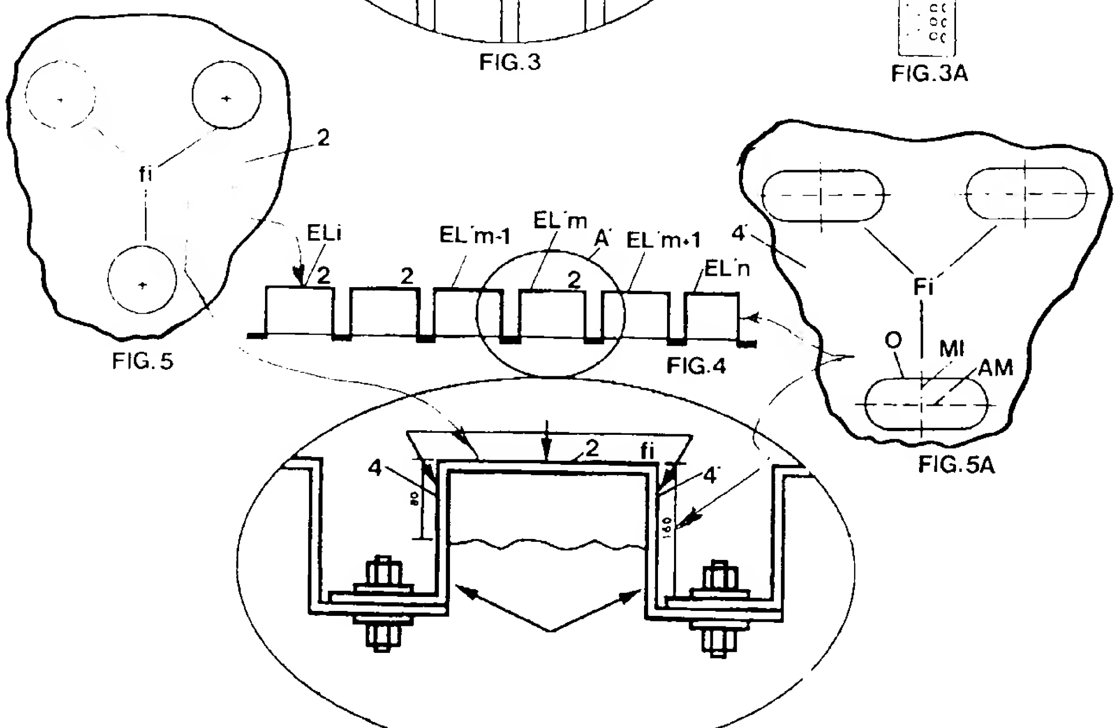



FIG.5

FIG.4

FIG.5A

FIG.4A

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# EUROPEAN SEARCH REPORT

Application Number

EP 92 10 0398

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
|---|---|---|---|
| Y | CH-A-344 716 (LONZA ELEKTRIZITATSWERKE UND CHEMISCHE FABRIKEN AG)<br>* page 1, line 1 - line 11 *<br>* page 2, line 6 - line 43 *<br>* figure 1 * | 1,3 | C07C273/04<br>B01J10/00<br>B01J19/24 |
| Y | EP-A-0 011 976 (G.G.HASELDEN)<br>* abstract *<br>* page 6, line 30 - page 11, line 9 *<br>* figures 1,2 * | 1,3 | |
| A | | 2,4 | |
| A | US-A-3 222 040 (J.S.ECKERT)<br>* column 1, line 10 - line 12 *<br>* column 1, line 34 - line 60 *<br>* column 2, line 49 - line 61 *<br>* figures 5,6 * | 3 | |
| A | US-A-3 049 563 (J.H.BOCHINSKI ET AL.)<br>* column 1, line 10 - line 15 *<br>* column 1, line 51 - line 57 *<br>* column 2, line 18 - column 3, line 46 *<br>* figure * | 1 | |

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B01J
C07C
B01D
B01F

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 16 APRIL 1992 | SIEM T.D. |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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